

MISFIRE DETECTING APPARATUS FOR INTERNAL COMBUSTION ENGINE AND METHOD THEREOF

Field of the Invention

The present invention relates to a misfire detecting apparatus for an internal combustion engine and a method thereof, for judging whether or not a misfire occurred, based on a variation of an engine rotation speed.

Related Art

Japanese Unexamined Patent Publication No. 04-171249 and Japanese Unexamined Patent Publication No. 58-051243 each disclose a misfire detecting apparatus in which diagnosis data indicating a variation of an engine rotation speed is calculated, and the diagnosis data and a threshold according to engine operating conditions are compared with each other, to judge whether or not a misfire occurred.

In an internal combustion engine, the engine rotation speed is varied due to a misfire, and is also varied due to the loosening of a flywheel or the deterioration of a clutch.

Further, during the rough road running of a vehicle, there is a case where the engine rotation speed is varied due to a change in power caused by a slight variation of an accelerator opening, or a change in traction of a driving wheel.

In the conventional technique, although the threshold to be compared with the diagnosis data is set according to the engine operating conditions, there is a problem in that it is erroneously judged that a misfire occurred, when the engine rotation speed is varied due to the factor as described above other than the misfire.

Summary of the Invention

The present invention has an object to provide a misfire detecting apparatus and a method thereof, which does not erroneously judge that a misfire occurred, when an engine rotation speed is varied due to a factor other than a misfire.

In order to achieve the above object, according to the present invention, in a configuration where it is judged whether or not a misfire occurred, based on the comparison between diagnosis data indicating a variation of an engine rotation speed and a threshold based on engine operating conditions, the threshold is corrected,

based on data indicating an average correlation between the diagnosis data and the threshold.

The other objects and features of this invention will become understood from the following description with reference to the accompanying drawings.

Brief Explanation of the Drawings

Fig. 1 is a diagram showing a system configuration of an internal combustion engine in an embodiment.

Fig. 2 is a flowchart showing an update control of a misfire frequency accumulated value in a first embodiment.

Fig. 3 is a flowchart showing an update control of correction coefficient in the first embodiment.

Fig. 4 is a flowchart showing a misfire judgment control in the embodiment.

Fig. 5 is a flowchart showing a second embodiment of the update control of the misfire frequency accumulated value.

Fig. 6 is a flowchart showing an update control of correction coefficient in the second embodiment.

Description of Embodiments

Fig. 1 is diagram showing a system configuration of an internal combustion engine in an embodiment.

In Fig. 1, an electronically controlled throttle chamber 104 is disposed in an intake pipe 102 of an internal combustion engine 101.

Electronically controlled throttle chamber 104 consists of a throttle valve 103b and a throttle motor 103a driving throttle valve 103b to open/close.

Air is sucked into a combustion chamber 106 of engine 101 via electronically controlled throttle chamber 104 and an intake valve 105.

An electromagnetic fuel injection valve 112 is disposed in an intake port 111 on the upstream side of intake valve 105.

Fuel injection valve 112 is driven to open by an injection pulse signal output from an engine control unit (to be abbreviated as ECU hereunder) 113, to inject fuel adjusted at a predetermined pressure toward intake valve 105.

Note, the configuration may be such that fuel injection valve 112 directly injects fuel into combustion chamber 106.

An air-fuel mixture formed in each cylinder is ignited to burn with the spark ignition by an ignition plug 114.

Ignition plug 114 is provided with an ignition coil 114A incorporating therein a power transistor.

ECU 113 performs a switching control of the power transistor, to control ignition timing (an ignition timing advance value) of each cylinder.

A combusted exhaust gas of engine 101 is discharged from combustion chamber 106 via an exhaust valve 107, and is purified by a front catalytic converter 108 and a rear catalytic converter 109, and then emitted into the atmosphere.

Intake valve 105 and exhaust valve 107 are driven to open/close by cams disposed to an intake side camshaft 110A and to an exhaust side camshaft 110B, respectively.

ECU 113 receives detection signals from an accelerator pedal sensor 116 detecting an accelerator opening APS, an air flow meter 115 detecting an intake air amount Q of engine 101, a crank angle sensor taking out a position signal POS for each unit crank angle from a crankshaft 121, a throttle sensor 118 detecting an opening TVO of throttle valve 103b, a water temperature sensor 119 detecting a cooling water temperature T_w of engine 101, a cam sensor 120 taking out a cylinder judgment signal PHASE from intake side camshaft 110A, and the like.

ECU 113 calculates an engine rotation speed N_e based on the position signal POS.

Further, ECU 113 has a function of judging an occurrence of misfire based on a variation of the engine rotation speed N_e . Such a misfire judging function will be described in accordance with flowcharts of Fig. 2 to Fig. 4.

The flowchart of Fig. 2 shows a routine executed every one ignition.

In step S1, an ignition counter for counting the number of ignition times is counted up.

In step S2, an engine load T_p and the engine rotation speed N_e are read.

Note, the engine load T_p can be represented by a basic injection quantity in fuel injection valve 112, a cylinder intake air amount, a throttle opening or the like.

In step S3, it is judged whether or not the engine load T_p and the engine rotation speed N_e read in step S2 are within previously set ranges, respectively.

Then, if the engine load T_p and the engine rotation speed N_e are within the previously set ranges, control proceeds to step S4.

In step S4, diagnosis data ΔN_e indicating the variation of the engine rotation speed N_e is calculated.

The diagnosis data ΔN_e is calculated as a deviation between the engine rotation speeds N_e calculated at two crank angle positions within one ignition cycle.

In step S5, referring to a map storing a basic threshold SL in each region, which is previously classified depending on the engine load T_p and the engine rotation speed N_e , the basic threshold SL corresponding to the engine load T_p and the engine rotation speed N_e at that time is calculated.

Further, in step S5, a final threshold SL is calculated based on the basic threshold SL and a correction coefficient K . An initial value of the correction coefficient K is 0.

Threshold SL = basic threshold + correction coefficient K x basic threshold

Note, the basic threshold SL is previously set for each of the engine load T_p and the engine rotation speed N_e , as a value at which the diagnosis data ΔN_e exceeds the basic threshold SL when a misfire occurred.

In step S6, it is judged whether or not the diagnosis data ΔN_e is equal to or above the threshold SL .

Then, if the diagnosis data ΔN_e is equal to or above the threshold SL and there is a high possibility of misfire occurrence, control proceeds to step S7, where a misfire counter for counting the number of misfire occurring times is counted up.

On the other hand, if the diagnosis data ΔNe is less than the threshold SL and it is judged that a misfire does not occur, control proceeds to step S8.

In step S8, an accumulated value $\Sigma \Delta Ne$ up to the previous time is added with the present diagnosis data ΔNe , to update the accumulated value $\Sigma \Delta Ne$.

In the next step S9, an accumulated value ΣSL up to the previous time is added with the present threshold SL, to update the accumulated value ΣSL .

In step S10, an accumulation counter for counting the number of accumulating times is counted up.

In step S11, it is judged whether or not a value of the ignition counter reaches 400, and if the value of the ignition counter = 400, control proceeds to step S12.

The ignition counter is reset to 0 when control proceeds to S12 and the subsequent steps as described later. Therefore, control proceeds to step S12 and the subsequent steps every 400 ignitions.

In step S12, a misfire frequency is calculated as a ratio between the value of the misfire counter and 400 as the total number of ignition times.

In step S13, it is judged whether or not a value of the accumulation counter is equal to or above a predetermined value A.

Then, if the value of the accumulation counter is less than the predetermined value A, and the number of samples of each of the accumulated value $\Sigma \Delta Ne$ and the accumulated value ΣSL is less than the predetermined value A, control proceeds to step S17.

In step S17, the misfire frequency presently obtained in step S12 is added to a misfire frequency accumulated value up to the previous time, to update the misfire frequency accumulated value.

The misfire frequency accumulated value is used for judging as to whether a final misfire judgment signal (misfire warning) is output, in a routine shown in the flowchart of Fig. 4.

On the other hand, in the case where the value of the accumulation counter is equal to or above the predetermined value A, that is, in the case where the number of

samples of each of the accumulated value $\Sigma\Delta Ne$ and the accumulated value ΣSL is equal to or above the predetermined value A, control proceeds to step S14.

In step S14, the correction coefficient K is updated, based on a ratio between the accumulated value $\Sigma\Delta Ne$ and the accumulated value ΣSL (ratio = $\Sigma\Delta Ne/\Sigma SL$).

The process in step S14 is described in detail in the flowchart of Fig. 3.

In step S141, a deviation $\Delta\alpha$ between $\Sigma\Delta Ne/\Sigma SL$ and a previously set reference value is calculated.

$$\Delta\alpha = \Sigma\Delta Ne/\Sigma SL - \text{reference value}$$

Then, in step S142, a correction value ΔK of the correction coefficient K is set according to the deviation $\Delta\alpha$.

The correction value ΔK is set to a positive value, an absolute value of which is increased according to an increase of an absolute value of $\Delta\alpha$, when $\Delta\alpha$ is a positive value, while being set to a negative value, an absolute value of which is increased according to the increase of the absolute value of $\Delta\alpha$, when $\Delta\alpha$ is a negative value. Further, the correction value ΔK is set to 0 when $\Delta\alpha$ is 0.

In step S143, a result obtained by adding the correction value ΔK to the correction coefficient K up to the previous time, is made to be a new correction coefficient K.

$\Sigma\Delta Ne/\Sigma SL$, which is a value that becomes larger when the diagnosis data ΔNe becomes larger averagely to approach averagely the threshold SL, is data indicating an average correlation between the diagnosis data ΔNe and the threshold SL.

Note, a simple average value of the diagnosis data ΔNe is obtained if $\Sigma\Delta Ne/\text{the number of accumulating times}$, and a simple average value of the threshold SL is obtained if $\Sigma SL/\text{the number of accumulating times}$. However, since $(\Sigma\Delta Ne/\text{the number of accumulating times})/(\Sigma SL/\text{the number of accumulating times}) = \Sigma\Delta Ne/\Sigma SL$, the division by the number of accumulating times is omitted.

Further, in the calculation of $\Sigma\Delta Ne$ and ΣSL , the diagnosis data ΔNe and the threshold SL for when the occurrence of misfire is judged, are eliminated from the samples.

Accordingly, the average correlation between the diagnosis data ΔNe and the threshold SL , which is indicated by $\Sigma\Delta Ne/\Sigma SL$, shows an increase tendency of rotation speed variation due to a factor other than misfire.

Here, when $\Sigma\Delta Ne/\Sigma SL$ is larger than the reference value, it is a state where the diagnosis data ΔNe is averagely too closer to the threshold SL due to a factor other than misfire. In this case, since the diagnosis data ΔNe easily exceeds the threshold SL , there is a possibility of erroneous judgment of misfire.

Therefore, the threshold SL is increasingly corrected by increasingly correcting the correction coefficient K , that is, the threshold SL is increased by an averagely increased portion of the diagnosis data ΔNe , so that the diagnosis data ΔNe exceeds the threshold SL only when a misfire occurred.

On the other hand, when $\Sigma\Delta Ne/\Sigma SL$ is less than the reference value, since the threshold SL is too larger than an average level of the diagnosis data ΔNe , there is a possibility that the rotation speed variation due to misfire is not detected.

Therefore, the threshold SL is decreasingly corrected by decreasingly correcting the correction coefficient K , so that the diagnosis data ΔNe exceeds the threshold SL when a misfire occurred.

Namely, the correction coefficient K is corrected so that $\Sigma\Delta Ne/\Sigma SL$ approaches the reference value.

If the threshold SL is corrected in such a manner, it is possible to avoid the erroneous judgment of misfire when the rotation speed variation is increased due to a factor other than misfire, such as the loosening of a flywheel, the deterioration of a clutch or the rough road running of a vehicle, and also it is possible to judge reliably a misfire in a state where the rotation speed variation is averagely low.

Note, the correction result of the correction coefficient K is applied to the misfire judgment during the next 400 ignitions.

If the correction coefficient K is corrected as described above in step S14 in the flowchart of Fig. 2, then in the next step S15, it is judged whether or not $\Sigma\Delta Ne/\Sigma SL$ is equal to or above a cancellation judgment value.

As described in the above, since the correction result of the correction coefficient K is applied to the misfire judgment during the next 400 ignitions, there is

the case where the misfire judgment in step S6 is performed according to the threshold SL based on the correction coefficient K adapted to the flat road driving up to the previous time, just after entering the rough road running.

Therefore, it is judged based on the comparison between $\Sigma\Delta Ne/\Sigma SL$ and the cancellation judgment value that the threshold SL is unable to follow an increasing change in average scale of the diagnosis data ΔNe .

Here, if $\Sigma\Delta Ne/\Sigma SL < \text{cancellation judgment value}$, the misfire frequency calculated in step S12 is considered to be detected based on an appropriate threshold SL, and then control proceeds to step S17.

On the other hand, if $\Sigma\Delta Ne/\Sigma SL \geq \text{cancellation judgment value}$, since the diagnosis data ΔNe is averagely too closer to the threshold SL, there is a possibility of erroneous judgment of misfire, and then control proceeds to step S16.

In step S16, it is judged whether or not the misfire frequency obtained in step S12 is equal to or above a predetermined value.

Then, if the misfire frequency is equal to or above the predetermined value, control proceeds to step S17, where the misfire frequency accumulated value is updated. If the misfire frequency is less than the predetermined value, control proceeds to step S18, where 1 is set to a cancellation flag.

In the case where $\Sigma\Delta Ne/\Sigma SL$ is equal to or above the cancellation judgment value, there is a possibility of erroneous judgment of misfire. However, if the misfire frequency is equal to or above the predetermined value, there is a high possibility that a misfire actually occurred even if the rotation speed variation is increased caused by a factor other than misfire, such as the loosening of the flywheel, the deterioration of the clutch or the rough road running of the vehicle. Accordingly, control proceeds to step S17, where the misfire frequency accumulated value is updated.

In the case where $\Sigma\Delta Ne/\Sigma SL$ is equal to or above the cancellation judgment value and also the misfire frequency is less than the predetermined value, there is a possibility of erroneous judgment of misfire although a misfire does not actually occur. Accordingly, control proceeds to step S18, where 1 is set to the cancellation flag, so as to cancel a final misfire judgment based on the misfire frequency accumulated value described later.

If the accumulation counter has a value less than the predetermined value A

and the number of samples of diagnosis data ΔNe for when the accumulated values $\Sigma \Delta Ne$ and ΣSL are obtained, it is impossible to judge with high accuracy an influence, such as the loosening of the flywheel, the deterioration of the clutch or the rough road running of the vehicle, on the diagnosis data ΔNe , based on $\Sigma \Delta Ne / \Sigma SL$.

Therefore, the correction of the correction coefficient K based on $\Sigma \Delta Ne / \Sigma SL$ and the setting of the cancellation flag based on $\Sigma \Delta Ne / \Sigma SL$ are performed when the accumulation counter has a value equal or above the predetermined value A .

Then, if the accumulation counter has the value less than the predetermined value A , control proceeds to step S17, where the misfire frequency accumulated value is updated, to avoid the erroneous correction of the correction coefficient K and the erroneous cancellation of misfire judgment.

In step S19, the ignition counter, the accumulation counter, the misfire counter, and the accumulated values $\Sigma \Delta Ne$ and ΣSL , are cleared, to terminate the present routine.

The flowchart of Fig. 4 shows a routine executed every 2000 ignitions. In step S31, it is judged whether or not 1 is set to the cancellation flag.

If 1 is set to the cancellation flag, control proceeds to step S32, where the misfire frequency accumulated value and the cancellation flag are cleared to terminate the present routine.

Accordingly, in the case where the correction of the threshold SL is unable to follow the averagely increase of the diagnosis data ΔNe by the influence, such as the loosening of the flywheel, the deterioration of the clutch or the rough road running of the vehicle, it is possible to prevent the erroneous misfire warning, thereby enabling the improvement of reliability of misfire judgment.

On the other hand, if it is judged in step S31 that 0 is set to the cancellation flag, control proceeds to step S33, where it is judged whether or not the misfire frequency accumulated value is equal to or above a predetermined value X .

The misfire frequency is obtained every 400 ignitions while the present routine is executed every 2000 ignitions. Therefore, the misfire frequency accumulated value to be compared with the predetermined value X in step S33 becomes a value obtained by accumulating sequentially the misfire frequency obtained every 400 ignitions by the five numbers of times.

If it is judged in step S33 that the misfire frequency accumulated value is equal to or above the predetermined value X, control proceeds to step S34, where the misfire warning is given to a driver by means of a warning device 123, such as a lamp, a buzzer or the like.

Note, the configuration of the present embodiment has been such that the output of the final misfire judgment signal is an output of an operation signal of warning device 123. However, the present invention is not limited thereto, and the configuration may be such that, for example, the misfire judgment signal is made a prohibition signal of the lean air-fuel ratio combustion, to forcibly shift a target air-fuel ratio from a lean air-fuel ratio to a stoichiometric air-fuel ratio.

In step S35, the misfire frequency accumulated value is cleared, to terminate the present routine.

In the above embodiment, the configuration has been such that $\Sigma\Delta Ne/\Sigma SL$ is calculated as the data indicating the average correction between the diagnosis data ΔNe and the threshold SL. However, it is possible that $\Delta Ne/SL$ is calculated at each time when the diagnosis data ΔNe is calculated, and this $\Delta Ne/SL$ is accumulated. An embodiment having such a configuration is shown in flowcharts of Fig. 5 and Fig. 6.

The flowchart of Fig. 5 differs from the flowchart of Fig. 2 only in steps S8A, S9A, S14A and S15A. Therefore, the steps in the flowchart of Fig. 5, which execute the same processing as in the steps in the flowchart of Fig. 2, are denoted by the same numerals as in the flowchart of Fig. 2, and the description thereof is omitted.

In step S8A in the flowchart of Fig. 5, a ratio between the presently calculated diagnosis data ΔNe and the threshold SL (ratio = $\Delta Ne/SL$) is calculated.

In step S9A, the accumulated value $\Sigma(\Delta Ne/SL)$ of $\Delta Ne/SL$ is updated.

Then, $\Delta Ne/SL$ is accumulated between each 400 ignitions, and control proceeds to step S14A, where the correction coefficient K, is updated based on the accumulated value $\Sigma(\Delta Ne/SL)$ /the number of accumulating times, that is, an average value of $\Delta Ne/SL$.

In step S15A, it is judged whether or not the accumulated value $\Sigma(\Delta Ne/SL)$ /the number of accumulating times is equal to or above the previously set cancellation judgment value.

In the present embodiment, the average value of $\Delta Ne/SL$ is the data indicating the average correlation between the diagnosis data ΔNe and the threshold SL .

The correction process of the correction coefficient K in step S14A is described in detail in the flowchart of Fig. 6.

In step S141A, the deviation $\Delta\alpha$ is calculated.

$$\Delta\alpha = \Sigma(\Delta Ne/SL)/\text{the number of accumulating times} - \text{reference value}$$

In step S142, the correction value ΔK is set according to the deviation $\Delta\alpha$, so that the accumulated value $\Sigma(\Delta Ne/SL)/\text{the number of accumulating times}$ approaches the reference value, and in step S143, the correction coefficient K is updated based on the correction value ΔK .

Further, in the case where it is judged in step S15A that the accumulated value $\Sigma(\Delta Ne/SL)/\text{the number of accumulating times}$ is less than the cancellation judgment value, it is judged that the misfire judgment is performed based on the appropriate threshold SL , and then control proceeds to step S17, where the misfire frequency is accumulated.

On the other hand, in the case where the accumulated value $\Sigma(\Delta Ne/SL)/\text{the number of accumulating times}$ is equal to or above the cancellation judgment value, it is judged in step S16 whether or not the misfire frequency is equal to or above the predetermined value. Then, in the case where the misfire frequency is less than the predetermined value and it is not an apparent misfire condition, it is estimated that the threshold SL is not changed following the influence due to such as the loosening of the flywheel, the deterioration of the clutch or the rough road running of the vehicle, and then control proceeds to step S18, where 1 is set to the cancellation flag.

Further, if the misfire frequency is equal to or above the predetermined value, it is judged that a misfire actually occurred even if the threshold SL does not follow the influence by the loosening of the flywheel or the deterioration of the clutch, or the rough road running of the vehicle, and therefore, control proceeds to step S17, where the misfire frequency is accumulated.

Note, in the above embodiment, the configuration has been such that timing for obtaining the average correlation between the diagnosis data ΔNe and the threshold SL is every 400 ignitions, and the final misfire judgment is performed every

2000 ignitions. However, it is apparent that the present invention is not limited to such number of ignition times.

Further, the configuration may be such that 400 ignitions interval during which the average correlation between the diagnosis data ΔNe and the threshold SL is obtained, and 400 ignitions interval during which the misfire judgment is performed based on the threshold SL corrected with the correction coefficient K set based on the average correlation, are distinguished from each other, to execute alternately the detection of average correlation and the adoption of correction based on the correlation.

The entire contents of Japanese Patent Application No. 2003-120325 filed on April 24, 2003, a priority of which is claimed, are incorporated herein by reference.

While only selected embodiments have been chosen to illustrate the present invention, it will be apparent to those skilled in the art from this disclosure that various changes and modifications can be made herein without departing from the scope of the invention as defined in the appended claims.

Furthermore, the foregoing description of the embodiments according to the present invention is provided for illustration only, and not for the purpose of limiting the invention as defined in the appended claims and their equivalents.